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SCIENCE

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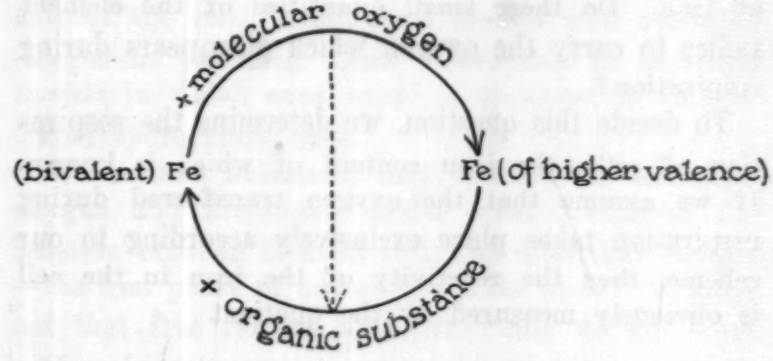
IRON, THE OXYGEN-CARRIER OF RESPIRATION-FERMENT[1]

THE idea that iron plays a part in the oxidation reactions of the living cell has appeared in a more or less definite form in the literature of the last fifty years. But since it was not possible to establish the idea and to differentiate it as correct from the false ideas which appeared at the same time, it was dropped and became worthless for science.

I

We maintain that in respiring cells there is a cycle of the form



In this cycle molecular oxygen reacts with bivalent iron, whereby iron in a higher state of oxidation is formed. The oxidized iron reacts with the organic substance and is again reduced to bivalent iron. Reactions in the direction of the dotted arrow do not occur; molecular oxygen never reacts directly with the organic substance.

According to this figure the organic substance is as little autoxidizable inside the cell as outside, the iron *alone* being autoxidizable. We know that iron can react with molecular oxygen in a test tube. Then, if our scheme is true, the problem of respiration ceases to exist, because it is solved if we are able to trace back the process of respiration to the reactions which occur in the test tube.

Not every form of bivalent iron reacts with molecular oxygen, and not every form of iron of higher valence reacts with organic substances. In order that iron may act catalytically according to our scheme, certain conditions with respect to the form in which the iron is present must be satisfied. It will be our problem to show that catalytically active forms of iron occur in living cells and in what way such forms of iron can be prepared by the chemist.

[1] Lecture delivered at the Rockefeller Institute for Medical Research, New York.

II

Our assertion assumes that every living cell contains iron and that life without iron is impossible.

Those who have cultivated cells know that this assumption is correct. Every nutrient medium must contain iron and the growth of the cells ceases when the iron is consumed. Although the necessity of iron for life was recognized by Eusèbe Gris sixty years ago, it has remained unexplained. The problem became more obscure when the fact was shown that iron does not take any part in the constitution of the organic molecule which occurs in the cell. The pure proteins, nucleic acids and chlorophylls do not contain iron.

The quantities of iron which occur in the cell are small. We have determined the iron content of different types of cells and found per gram of cell-substance one tenth to one hundredth of a milligram of iron. Do these small quantities of the element suffice to carry the oxygen which disappears during respiration?

To decide this question, we determine the respiration of cells, the iron content of which is known. If we assume that the oxygen transferred during respiration takes place exclusively according to our scheme, then the reactivity of the iron in the cell is obviously measured by the quotient

$$\frac{\text{oxygen consumption}}{\text{iron content} \times \text{times}}.$$

If we choose as units cubic millimeters of oxygen, milligrams of iron and hours, then our quotient becomes, for example:

For the unfertilized Strongylocentrotus-Egg at 20°	7,000
For the fertilized Strongylocentrotus-Egg at 20°	42,000
For the retina of mammals, the organ of higher animals which has the largest respiration, at 37°	100,000

Let us compare the reactivity of iron in the test tube with these figures. If, for example, we consider the oxidation of cystein to cystin, which is accelerated by iron salts, and determine how much oxygen 1 milligram of iron transfers per hour, when added to an aqueous solution of cystein, we find at 20° 120,000 cubic millimeters of oxygen and at 37° 400,000 cubic millimeters, that is, larger values than for the reactivity of iron in living cells.

This calculation shows that the iron content of a cell more than suffices to explain the oxygen consumption incident to respiration according to our assumption. The iron content of a cell is small to the quantitative chemist, but large for us in consideration of the reactivity of the element.

As is known, the living cell contains not only iron among the autoxidizable metals, but also copper, manganese and other metals. One might ask if it would not be better to write "heavy metal" instead of "iron" in our scheme. We do not do this, because we do not know if copper and manganese are necessary for life, and because, in comparison to their reactivity the quantities of these metals are small. According to Bertrand and Medigreceanu, 1 gram of cell substance contains one ten thousandth of a milligram of manganese, that is, the manganese content of a cell is a hundred to a thousand times smaller than the iron content. If the oxygen, which disappears during respiration, were carried by this amount of manganese, then the reactivity of the manganese in the cell would be ten million, greatly exceeding that which we find for the element in the test tube.

Therefore we confine our assumption explicitly to iron and consider its application to other heavy metals for the present as unfounded. There may be exceptions—one is reminded of the copper of the octopus and of the fact discovered by Henze that the ascidia contain vanadium—but such cases do not belong in a general theory of respiration.

III

According to our assumption, every substance which reacts with iron must interfere with oxygen transfer in the cell, provided that it penetrates the living cells and that its affinity for iron suffices to loosen the natural combinations with this element. Substances which react with iron are arsenious acid, hydrogen sulfide, prussic acid and such others as, when introduced into the cell, retard respiration.

We have studied the effect of prussic acid in greatest detail. Prussic acid is by no means a general ferment poison. Even one tenth normal prussic acid has no noticeable effect on hydrolyzing ferments. On the other hand, prussic acid in small concentrations has an effect on all those processes in which the combination and transfer of oxygen play a part, as for example, the assimilation of carbon dioxide, nitrate assimilation, the decomposition of hydrogen peroxide and respiration. These processes are retarded by prussic acid in concentrations of 1/10,000 to 1/100,000 normal. By direct measurement it can be shown that the cell takes very little prussic acid out of such a dilute solution, an amount which is very small compared with the weight of the cell.

Since a stoichiometrical relation must exist between the combined prussic acid and the substance with which it combines, it follows from what has been said that the cell contains a minute amount of some substance which is able on the one hand to transfer

oxygen and on the other hand to react with prussic acid. Of all the substances which occur in the cell the only one which fulfills these conditions is iron. It is true that certain autoxidizable aldehydes can react with oxygen as well as prussic acid, but it is not known whether such aldehdyes are integral components of living cells.

IV

Until now we have presented a series of arguments in favor of our conception, namely, the necessity of iron for life, the large reactivity of iron, the specific effect of substances which react with iron, but we have presented no conclusive experiments. Is it possible to show directly that iron carries oxygen in the cell?

If the unfertilized eggs of Strongylocentrotus be centrifuged and shaken, the eggs dissolve and a liquid is obtained which respires as strongly as the intact eggs from which the liquid came. The liquid contains iron to the extent of some hundredths of a milligram per gram of cell substance. If iron is added to the liquid in such quantities as occur naturally in the egg substance, the oxygen consumption increases as does the increase in iron content. It is evident then that not only does the iron, when added to the cell substance, carry oxygen, but what is more significant, the oxygen consumption is proportional to the iron content of the cell substance.

This important experiment will be described more in detail. The respiration of the intact unfertilized eggs as well as their iron content is determined, and the reactivity of the iron calculated by dividing the respiration by the iron content. Then the eggs are dissolved, 1/100 milligram of iron is added to one gram of egg substance, and the increase in the oxygen consumption due to the iron is determined. From these figures the reactivity of the iron added is calculated. In both cases we find for the reactivity of the iron the value 7,000. This indicates that every milligram of iron, whether that of the intact egg or that which is added, carries the same quantity of oxygen per hour, that is, 7,000 cmm.

These experiments, which I carried out ten years ago, partially in cooperation with Otto Meyerhof, prove that our hypothesis is correct, at least in the case of the sea urchin's egg.

V

Instead of substantiating for other cases what we found in the case of the sea urchin's egg, we immediately proceeded to the problem of reproducing the same effects of iron in simple systems, which are free from the ballast of the cell substance.

The experiments which we now consider are model experiments, inasmuch as the conditions under which we work are simpler than in the case of the cell. Indeed, the experiments are to be considered more than model experiments, if the transfer of oxygen to the combustibles of the cell with the help of iron is successful. For then the natural process of oxygen transfer is not only imitated in the test tube, but the oxygen transfer in the test tube and in the cell is identical, the basis of the transfer in both cases being the change in valence of the iron.

It is not permitted in such experiments to use oxygen in an activated form, such as ozone, hydrogen peroxide or quinone. Activated oxygen, especially in the presence of iron, will attack, as shown by Fenton, Dakin and Neuberg, all organic molecules; but the point to be explained is why molecular oxygen inside of the cell behaves like activated oxygen outside of the cell. Respiration models with activated oxygen as oxidizing agent correspond to invertase models in which cane sugar is dissolved in concentrated hydrochloric acid.

We confine ourselves, then, strictly to molecular oxygen and investigate under what conditions the reaction between bivalent iron and molecular oxygen —the first phase of our cycle—takes place. It turns out that free ferrous ions practically do not react with molecular oxygen and hence can not transfer it. On the other hand, certain complex ferrous salts, when in solution, as well as certain solid iron compounds, react quickly with molecular oxygen. In this connection I should like to mention the interesting work of Baudisch. However, if amino acids or sugar are added to ferrous compounds which react quickly with oxygen, in general no transfer of oxygen takes place.[2] The absorption of oxygen by such mixtures ceases when the iron is oxidized. It is just as difficult to bring about the second phase of our cycle—the reaction between iron of higher valence and organic substance—as it is easy to bring about the first phase.

Obviously there are only certain specific and until now unknown compounds of iron which can act catalytically in the sense of our hypothesis. How such compounds are formed and what effects they produce will now be described.

VI

If pure crystallized hemin, an iron compound of pyrrol, is heated strongly to glowing, a black residue is obtained which after extraction with hot hydro-

[2] Recently H. A. Spoehr has observed that iron pyrophosphate is able to transfer oxygen to glucose with result that carbon dioxide is formed.

chloric acid contains, together with carbon, 3 per cent. nitrogen and as much iron. This charcoal acts as an oxidation catalyzer for amino acids. When added to an aqueous solution of amino acids and shaken with air or oxygen at body temperature, the oxygen is absorbed and carried to the amino acids. With leucine ammonia, carbon dioxide and valeric aldehyde are formed; with cystine ammonia, carbon dioxide and sulfuric acid, together with unknown products of the incomplete combustion. We have then a reaction between amino acids and oxygen, in which, as in the case of the combustion of proteins in the living cell, ammonia, carbon dioxide and sulfuric acid appear.

If we ask which constituents of the hemin charcoal are catalytically active here, then the same difficulty in principle arises as in the experiments with living cells. Given a mixture of different substances, we have to decide which constituents of the mixture cause the observed effect. In practice, however, we have the great advantage that we can prepare the catalytically active mixture artificially. In order to decide our question it is necessary merely to heat different substances to glowing and to compare the catalytic action of the charcoals formed with their chemical composition.

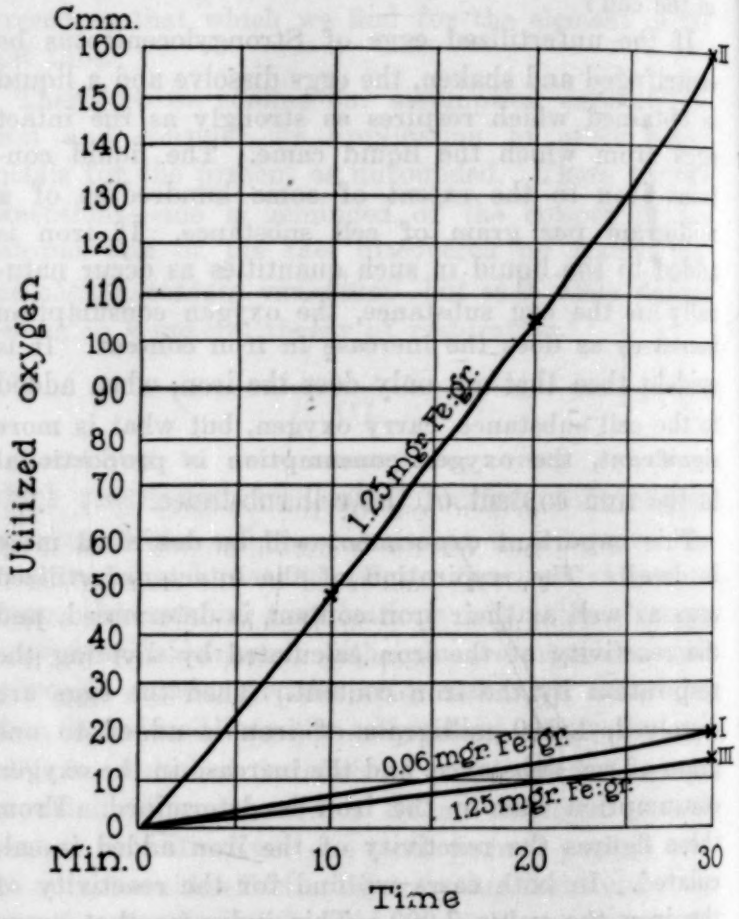
We have carried out experiments of this kind. In these it developed that charcoals having the catalytic effect of hemin charcoal are always formed when two conditions are satisfied, first, when the starting material contains non-volatile nitrogen, and second, when it contains iron. If suitable substances containing nitrogen are carefully purified so that they contain very little iron and then heated to glowing, weakly active charcoals are formed. If these be impregnated with iron salt and then heated to glowing, they become activated and attain the catalytic activity of hemin charcoal. The richer the charcoals are in iron, the more active they are, until the maximum of reactivity is reached at an iron content of some tenths of a milligram per gram of charcoal.

There is no activation if charcoals containing nitrogen with other metals or charcoals free from nitrogen are heated to glowing with iron. Hence, the catalytically active substance of hemin charcoal is iron, not iron in any form, but in combination with nitrogen.

We do not maintain that only iron can carry oxygen to amino acids: rather we have found that charcoals made from pure sucrose free from iron also possess a certain catalytic activity. However, this activity, which is due to the action of a carbon peroxide, is not to be compared in magnitude with the action of iron combined with nitrogen. The best charcoals free from iron which we obtained are 500 times weaker in action than hemin charcoal, so that at least 99.8 per cent. of the action of hemin charcoal must be due to iron.

VII

The catalytic action of iron combined with nitrogen, like the respiration of living cells, is retarded by prussic acid. One ten thousandth normal prussic acid markedly reduces the activity of hemin charcoal and of all other iron-nitrogen charcoals which we have prepared. One thousandth normal prussic acid causes the catalytic activity practically to disappear. I do not hesitate to see in this result a striking confirmation of our hypothesis.



A figure will make clear the main experiments. The abscissae represent time, the ordinates the transferred oxygen. In our example the amino acid, to which the oxygen is carried, is leucine, while the charcoals, which carry the oxygen, were prepared from an aniline dye rich in nitrogen. Curve 1 shows the transfer of oxygen by a charcoal which contains .06 mgr Fe per gram; curve 2 shows the transfer of oxygen by the same charcoal after its iron content had been increased to 1.25 mgr per gram by impregnation with iron salt and heating to glowing; curve 3 shows the transfer of oxygen by this charcoal rich in iron after adding 1/1000 mol prussic acid to liter of solution. As is seen, the activity of the char-

coal increases with its iron content and its action disappears completely under the influence of prussic acid.

VIII

As far as the activity of iron in its combination with nitrogen is concerned, we calculate it, as heretofore, by dividing the increase in oxygen consumption, which takes place when iron is added, by the amount of iron added. In the case represented by the figure, we find the value 12,000, which is approximately the reactivity of iron in the intact unfertilized sea urchin's egg, in other words the reactivity of iron combined with nitrogen is of the same order of magnitude as the reactivity of iron in the living cell.

Summarizing the results of the experiments with charcoal, we see that at body temperature and in neutral solution, with the help of iron, molecular oxygen can be carried to amino acids whereby ammonia, carbon dioxide and sulfuric acid appear as decomposition products. This reaction, like respiration in the living cell, is specifically retarded by prussic acid.

IX

When bivalent iron reacts with oxygen or when iron of higher valence reacts with the amino acids, then the driving forces are specific chemical forces. In the transfer of oxygen by hemin charcoal the general surface forces play an important part, together with the specific chemical forces, inasmuch as they bring the amino acid out of the solution on to the iron. Substances of the most dissimilar chemical properties, if they are adsorbed by the charcoal, can displace the amino acids from the charcoal. This displacing action of a substance is determined by the force with which the surface attracts the substance one which is proportional to the adsorption constant. The greater the adsorption constant, the greater is the displacing action, which proves that the general surface forces hold the amino acids and catalyzer together.

Physical chemistry has shown that chemical reactions can be accelerated by the action of general surface forces. Porcelain, quartz and other solids accelerate the reaction of hydrogen and oxygen to form water. The hydrogen and oxygen become more reactive under the influence of the surface forces, and we must assume the same in our case for the amino acids, the structure of which is loosened by the surface forces.

However, this loosening does not suffice to cause the amino acids and oxygen to react. Charcoals which contain neither iron nor carbon peroxide, even if they adsorb well, are catalytically completely inactive. A reaction takes place only when chemical forces are present together with surface forces.

Thus that peculiar combination of general surface forces and specific chemical forces arises which is characteristic of our model as well as of the living substance. Both systems react on the one hand like general surface catalysts, on the other hand like specific metal catalysts. The specific negative catalyst is prussic acid; the general negative catalysts are the narcotics.

X

If the idea of activation is carried far enough, then iron of higher valence plays the part of "activated" oxygen and the atoms of the loosened organic molecules are "activated" carbon, hydrogen, sulfur, etc. All the molecules which take part in the process of respiration are activated, the oxygen by chemical forces and the other molecules by general surface forces.

This conclusion shows that the former theories of respiration were partly correct and partly false. The theories of Moritz, Traube, Bach and Engler were correct in so far as they assumed an activation of oxygen, but false in so far as they overlooked the activation of the organic molecules. The theories of Pfeffer and Wieland were correct in so far as they assumed an activation of the organic molecules but false in so far as they denied the activation of the oxygen.

The most unsatisfactory element of the older theories of respiration was their vagueness. To say that a ferment activates the reacting substances is merely another expression for the fact that it acts. Invertase activates cane sugar; zymase activates dextrose.

The problem to be solved is not whether a ferment activates but in what way it activates. If we content ourselves with answering the first question, then we have an argument in a circle which explains respiration by means of activation and activation by means of the activating ferments.

XI

The iron of the hemin charcoal attacks with an appreciable velocity only a limited number of the many organic substances. Of the principal combustibles of the cell neither the sugar nor the fatty acids but only the amino acids are attacked. The selective action of our model seems more marked than that of the living cell.

On the other hand the combustion of carbohydrate and fat in the living cell is as much an iron catalysis as the combustion of amino acids. For the combustion of carbohydrate and fat in living cells is specifically retarded by prussic acid.

The contradiction disappears if we expand our assumptions with the hypothesis that of the three principal combustibles only the amino acids are at-

tacked directly by iron, while the carbohydrates and fats do not react as such with the iron, but in the form of unknown derivatives. If this is true, then we must look for reactions, which are not oxidation reactions, but splittings or condensations, which take a part in respiration in so far as they make the attack of the iron possible. We have found a reaction of this kind in which sugar is changed into a reactive form.

If oxygen be passed through a neutral solution of fructose and sodium phosphate at body temperature, the oxygen disappears and the higher the phosphate concentration the quicker the disappearance. Fructose, when dissolved in other salt solutions, does not absorb oxygen, and other sugars, when dissolved in phosphate solutions, absorb very little oxygen in comparison with fructose. Thus a specific reaction between fructose and phosphate is concerned here, whereby a reactive substance is formed. This substance is not the much investigated hexose-phosphate-acid, which is stable in the presence of oxygen.

The rate of oxidation of fructose in the presence of phosphate is large under suitable conditions; 0.3 per cent. of the fructose present at any time can be destroyed per hour.

Carbon dioxide is formed as a product of the reaction, and per molecule of oxygen used, one third of a molecule of carbon dioxide appears. Thus the oxidation is not complete, as in the case of living cells, but nevertheless yields in large quantities the physiological end product of carbohydrate combustion.

It is remarkable that till now this simple and important reaction has been overlooked. The reaction is important because we have here a partial combustion of carbohydrate in the test tube under the influence of a substance which is an integral part of living cells.

At first this case seems to contradict our assertion that not the organic substance but only the iron of the cell is autoxidizable. For is not the sugar affected in such a way through combination with phosphate that molecular oxygen attacks it? This is not true, but, as shown by Otto Meyerhof, the autoxidizable component of the system is here also a metal.

Meyerhof observed the following: If 1/1,000 mol of sodium pyrophosphate be added to a solution of fructose in N/2 phosphate there is a strong retardation of the oxidation. The same is the case if 1/10,000 prussic acid be added to the weakly alkaline solution. Both substances, pyrophosphate and prussic acid, are characterized in that they form stable, complex compounds with metals, and both cases are understandable if we assume that the fructose oxidation in a solution of phosphate is caused by the action of metals which are always present to a small extent in the laboratory reagents.

As a matter of fact, small quantities of copper, manganese and iron, when added to the fructose-phosphate mixture, strongly accelerate the oxidation. Meyerhof obtained the strongest action of the metals in a weakly alkaline solution and found, for example, that 1/100 milligram of copper, when added to 100 milligrams of fructose, accelerated the oxidation 140 per cent., and 1/100 milligram of iron 70 per cent.

Of course the degree of acceleration depends upon the purity of the fructose-phosphate mixture and would be infinitely great if we had solutions free from iron at our disposal. Under such conditions it is more appropriate to disregard the oxidation before the addition of metal and to consider only the increase in the oxygen absorption which takes place with the addition of metal. If we do this and divide the increase of oxygen consumption by the metal added, we obtain the reactivity of the metal in the system fructose-phosphate. We calculate from an example of Meyerhof for copper 20,000, and for iron 10,000, which is of the order of magnitude of the reactivity of iron found for living cells.

In summary, if inorganic phosphate and fructose are brought together in aqueous solution, a substance is formed which combines with iron, changing it into a catalytically active form. Iron in this form reacts quickly with molecular oxygen and the iron which is formed in a higher state of oxidation reacts quickly with the organic substance, being reduced again to bivalent iron.

This is the cycle of our scheme which here partially combusts the carbohydrate to carbon dioxide, a process which, like the combustion of carbohydrates in the living cell, is specifically retarded by prussic acid.

The significance of the system fructose-phosphate-iron lies in the fact that it is built up exclusively of substances which occur in the cell, and that here, as we must assume, one of the physiologically active forms of iron is present. In this respect the system is a better model than the charcoal model in which the combination of iron is not physiological. On the other hand, the surfaces are lacking in the fructose system, which necessitates high and non-physiological concentrations and makes it non-narcotizable.

XII

The problem of attacking fats by means of iron in the test-tube is for the most part still to be solved. Nevertheless, the little that has been done is of interest because one of the combinations of iron occurring in the cell—the combination with the SH group—plays a part here.

Thunberg found that iron salts accelerate the oxidation of aqueous lecithin suspensions. We have stud-

ied the reaction more closely and found that iron salts act similarly on linolenic acid, that the double bonds of the linolenic acid are attacked in the reaction and that the taking up of oxygen ceases when two of the three double bonds have disappeared. Thus the action of the iron is not strong and not to be compared with the action of iron on the fructose in our models; but still we have here a system which is built up exclusively of substances that occur in the cell.

Meyerhof found that in the system linolenic-acid-iron the iron can be replaced by the SH — group. Hopkins showed the same to be the case for the SH — group of the glutation which, according to his discovery, is quite a common constituent of living cells. So it seemed that the SH — group, like iron, can take up and carry oxygen, which contradicts our assertion that iron is the only autoxidizable component of the cell.

The contradiction becomes even stronger if we add that, according to Mathews and Walker, the autoxidation of cystein is retarded by prussic acid. When Mathews and Walker added prussic acid to a neutral cystein-solution the oxygen absorption ceased. According to this it seemed that the SH — group, like iron, not only carries oxygen, but also, like iron, is inactivated by prussic acid, which contradicts our assertion that prussic acid effects the absorption of oxygen only in that it combines with iron.

If we consider the experiments of Mathews and Walker more closely, we hit upon a difficulty. If prussic acid inactivates the SH — group, then it must combine with it, and the amount of prussic acid must be stoichiometrically related to and of the same order of magnitude as the amount of cystein which it inactivates. However, the figures of Mathews and Walker show that one molecule of prussic acid inactivates 1,000 and more molecules of cystein. As this is contradictory to the laws of chemistry, we have taken the stand that the autoxidation of cystein is in reality not an autoxidation, but is due to the action of traces of catalytically active metals, which, under the experimental conditions of Mathews and Walker, must have always been present as impurities in their solutions.

In order to test this we worked out a method of purification for cystein, carried out our experiments in quartz instead of glass vessels, and, which was no doubt the vital point, prepared the alkali for the neutralization of the cystein-chlorhydrate by distillation in quartz vessels. It thereby developed that the oxygen absorption by the cystein solutions became less and less as the purity of the solutions increased. While the purest preparations of Mathews and Walker were one half oxidized in a few hours when shaken with air, 14 days were necessary in our best experiments to oxidize half the cystein under otherwise similar conditions. If we added iron to these preparations they assumed the properties of the preparations described by Mathews and Walker.

What held up a true knowledge of the facts so long was that one was not accustomed to deal with the quantities of iron which are active in the cystein catalysis. Some 1/100,000 mgr of iron when added to 10 cc of a solution of cystein cause a large and easily measured absorption of oxygen, while it is hardly possible to test for iron at such dilutions with the customary reagents.

In summary, cystein free from metal does not react with molecular oxygen and therefore can not carry it. In solutions containing metal, it is the metal which carries the oxygen and this transfer of oxygen, like the other metal-catalyses, is retarded by prussic acid. This case, which at first seemed to be irreconcilably opposed to our views, becomes, on closer examination, a very simple and striking argument for the truth of our theory.

Our experiments do not indicate that the SH — group is insignificant for respiration; rather they show wherein it is significant. By combining with the SH — group iron attains a reactivity which is greater than that of any of the known combinations. Iron, combined with the SH — group of cystein, reacts ten times as fast as the iron in charcoals containing nitrogen or the iron in the fructose-phosphate mixture.

XIII

If we survey the three models discussed—hemin charcoal-amino acids, fructose-phosphate and cystein-linolenic-acid—and compare the effects of iron, we recognize that in each the combination of iron has a decisive influence upon its action. Iron combined with the nitrogen of the charcoal attacks neither the fatty acids nor sugar, but only the amino acids. Iron combined with fructose-phosphate attacks neither amino acids nor fatty acids but only sugar and of these only fructose with an appreciable velocity, so that it would not be difficult with the help of this artificial system to separate fructose from galactose as completely as with the help of fermenting yeast cells. Iron, combined with the SH — group, attacks neither amino acids nor sugar, but only fatty acids and of these only the unsaturated ones.

This contrast shows upon what the specific action of respiration depends. To be sure, it is always the same atom which takes up the oxygen and transfers it, and it is always the same process—the change in valence—which is the basis of the oxidation, but whether and how quickly this change of valence takes place depends upon how the iron is combined. Therewith the specific action is explained so far as it is

possible in the present stage of physical chemistry. Why iron in the one combination reacts quickly, and in the other combination slowly, we can not explain any more than we can explain the velocity of any chemical reaction. The mechanism of chemical reactions is unknown.

XIV

If we ask ourselves in conclusion: "What is the respiration ferment?" the answer depends upon how far we carry the idea of respiration. If we confine it to the oxidation process, then the respiration ferment is the sum of all the catalytically active iron compounds which occur in the cell. If we consider as a part of respiration reactions in which, as in the reaction between fructose and phosphate, specific affinities for iron arise, then all substances which, by a splitting or condensation, allow iron to combine, are also constituents of the respiration ferment. Whether we comprehend the idea of respiration in a narrow or broad sense, iron will always maintain its central position as the oxygen-carrying component of the respiration ferment. For oxidation is that process by means of which respiration is differentiated from the other ferment-reactions and in which the purpose of respiration, the production of energy, is fulfilled.

OTTO WARBURG

BERLIN-DAHLEM
GERMANY

JOHN MUIR, NATURALIST AND POET

OF the naturalist-poets of our time, two stand out above the others, the writings of both permeated with a lofty optimism—Burroughs and Muir. John Burroughs "accepted the universe" with an eye on the unresting masses who, tormented by one another and with no time nor energy to look upward, find this world empty and meaningless like themselves.

John Muir went deeper than this, "treading the crust of the earth in adoration." He found "the love of wildness ever sounding in his ears," a world in which beauty, grandeur and fitness were always within the reach of men and where most of the disillusionment and misery of human kind were chiefly self-inflicted. "Freshness and beauty are everywhere," he writes; "flowers are born every hour, living sunlight is poured over all and every thing and creature is glad. Our world is indeed a beautiful one and . . . I would hardly accept a free ticket to the moon or to Venus or any other world for fear it might not be as fraught with the glory of the Creator as our own."

"The Life and Letters of John Muir," as prepared by his younger friend, Professor William Badé, gives an illuminating record of the thoughts and activities of one of the finest and rarest of men. Muir was great as an explorer and investigator. His studies of mountains and glaciers give him a high rank as an interpreter of phenomena. His sympathetic record of trees and beasts places him with the most intense of nature lovers. His exquisite choice of langauge, noticeable in letters and essays alike, has nowhere a touch of the artificiality of those who give nature their patronizing but ignorant approval. His warm friendships and freedom from bitterness display the fine mettle of his character.

In two plump volumes, as a labor of love, Professor Badé gives us a clear insight into Muir and his ways. Born at Dunbar, Scotland, on April 21, 1838, he came early to Wisconsin, where he entered the state university. He went thence to Indianapolis, intending to become a mechanical inventor. But his love for nature carried him out of the shops and set him on a thousand-mile tramp to the gulf. Still later he sought the greater wildness of the high Sierras. Here he became a shepherd in the foothills, but soon forsook the sheep, "hoofed locusts," he called them from their ruthless raids on forest vegetation. For years he devoted himself to the Yosemite Valley, its geology and its grandeur, modestly describing its scenery in letters to his friends, and later as his fame spread eastward, in many magazines. One of his finest essays, the best bird biography in existence, relates to the water-ouzel as seen at East Lake in the Kings' River Canyon. After emerging from the Yosemite, Muir retired to his farm at Martinez and devoted himself to writing. He interrupted this work with frequent rushes to the Sierras, Alaska, Australia and the ends of the earth. His later years were devoted to the efforts for the protection of the Yosemite and other like glacier-worn valleys which he called collectively "Yosemites," not forgetting their giant forests. "However man might slight these," he said, "God must be proud of them for they were the finest He ever planted."

In these efforts he was mainly successful, but not in the case of the noble Hetch-Hetchy Canyon of the Tuolumne, which he saw to his great grief condemned as a water supply to San Francisco.

Muir always refused to lecture, but to small circles he was a brilliant conversationalist. His general attitude appears in an answer to the assertion that "the world was made for man," a notion derived from "the huckster appraisement of Nature." "Certainly not," said Muir. "No dogma taught . . . forms so insuperable an obstacle to a right understanding of the relation which human culture shows to wildness. Every animal, plant or crystal controverts it in the plainest terms. Yet it is taught from century to century as something ever new and precious, and in the resulting darkness the enormous conceit is allowed to go unchallenged."

STANFORD UNIVERSITY DAVID STARR JORDAN

SCIENTIFIC EVENTS

JOHN FILLMORE HAYFORD

AT the annual meeting of the American Geophysical Union, May 1, 1925, the following resolutions were passed:

WHEREAS, we, the members of the American Geophysical Union, have learned with sincere regret of the death on March 10, 1925, of our associate, Dr. John Fillmore Hayford, director of the College of Engineering of Northwestern University; therefore, be it

Resolved, That we express our deep sorrow in the loss of this member whose active work in the American Geophysical Union began with its organization in 1919. He held the office of chairman of the section of geodesy from July 1, 1922, to June 30, 1924, and, not being eligible for immediate reelection, that of vice-chairman from July 1, 1924, until the time of his death.

Dr. Hayford enjoyed world-wide renown in the realm of geophysical science. For a number of years he was in general charge of the geodetic field and office work of the U. S. Coast and Geodetic Survey, during which time he unified the triangulation systems of the entire country by basing them upon a single point and on one spheroid of reference. He derived, from triangulation and astronomical data in the United States, a new spheroid which was adopted in 1924 by the section of geodesy of the International Geodetic and Geophysical Union as being the most reliable in existence and the one recommended for use in all mapping and charting purposes by those countries which have not already adopted a spheroid for such work.

Dr. Hayford, while in charge of the geodetic work of the U. S. Coast and Geodetic Survey, was instrumental in initiating the revision of field and office methods and practices in conducting geodetic work, leading to greater efficiency and economy. He made the first comprehensive quantitative investigation of the theory of isostasy and thereby proved its validity. In recognition of this he was awarded, early in 1924, the Victoria Medal by the Royal Geographical Society of London.

During the war Dr. Hayford was a member of the Advisory Committee on Aeronautics and, at the time of his death, was a research fellow of the Carnegie Institution of Washington, carrying on investigations concerning the levels of water in the Great Lakes.

The long list of scientific reports and papers by Dr. Hayford forms his fitting and lasting memorial.

Resolved, That the members of the American Geophysical Union regret the death of Dr. Hayford as a personal loss as well as a loss to the science of this country and the world and that they express to his family their deepest sympathy.

Resolved, At the annual meeting of the American Geophysical Union, held on May 1, 1925, that a copy of these resolutions be sent to Dr. Hayford's family and that they be spread on the minutes of the union.

THE STRUCTURE OF LIGHT[1]

THE first Fison Memorial Lecture was delivered by Sir Joseph Thomson in the Medical School, Guy's Hospital, London, on Thursday, May 7, the chair being taken by Lord Balfour. Sir Joseph selected as his subject "The Structure of Light," in the course of which he stated that the optical properties of light appear to be explicable only upon a wave theory, whereas the electrical properties are more easily explained on a corpuscular theory. Newton himself really combined the two theories, as the assumption of waves generated by the corpuscles was an essential part of his explanation of simultaneous reflection and refraction. The followers of Newton were "more corpuscular" than Newton himself, and a purely corpuscular theory of light was generally adopted until the work of Young and Fresnel once more focussed attention upon the wave theory. By the end of the nineteenth century, Maxwell's electromagnetic theory, and the pioneer experiments of Hertz and Lodge on electromagnetic waves, had made the wave theory of light probably the most complete and satisfactory in physical science. Then the study of gaseous ionization, the photoelectric effect, X-rays and black body radiation began to throw doubts upon the sufficiency of the ordinary wave theory.

As an alternative, Sir Joseph Thomson put forward a new theory designed to explain both electrical and optical properties of light (see *Phil. Mag.*, vol. 48 (1924), p. 737). Imagine an electron and a positive nucleus joined by a tube of force. If the electron jumps from one stable state to another of smaller energy, we may suppose that the tube of force is thrown into a loop, which becomes detached as a closed "ring of force." Such a ring would travel out like a vortex ring in a direction perpendicular to its own plane. It would also carry with it a definite "quantum" of energy. Immediately before and after the formation of the ring ordinary electromagnetic waves would also be started, but the ring would carry nearly all the energy liberated by the movement of the electron. Absorption of energy by an atom could take place by a converse process, and would normally occur only when the energy in the ring was sufficient to move an electron from one stable state to another, *i.e.*, when the energy was great enough to produce partial or complete ionization of the atom. The circumference of a ring of force would be equal to the wave-length of the light, and so a ring of visible light would be too large to be absorbed easily by an atom except by a process involving resonance, whereas an X-ray ring would be comparable in size to an atom. This would account for the observed differences between X-ray and optical absorption. The waves which

[1] From *Nature*.

accompany the ring would undergo interference and diffraction, and the rings would tend to follow the waves, so that the probability of a ring reaching a given point would depend upon the amplitude of the wave at this point. Thus interference and diffraction fringes would be statistical effects.

SEISMOLOGY IN CANADA

A SIXTH seismograph station, which will assist in the work of those maintained at Saskatoon, Halifax, and Ottawa, by the Dominion Observatory and at Victoria and Toronto by the Meteorological Service, has been established at Ste. Anne de la Pocatière, Quebec, by the Department of the Interior. The new station is situated near the center of the area affected by the earthquake of February 28. The Dominion Observatory does not anticipate any further serious shocks, and the object of the installation is to study better the slight tremors which may occur from time to time in this area as a natural consequence of the more intense quake, as well as to secure a seismological record for this part of Canada.

The major disturbance of February is still under investigation by the seismologist of the Dominion Observatory. In reply to a query in the House of Commons recently, the Honorable Charles Stewart, Minister of the Interior, presented an interim report on the earthquake investigations, which in part was as follows:

The data given in this preliminary report were gathered during a trip of investigation covering the north shore of the St. Lawrence between Quebec and Murray Bay, the south shore from Lévis to Trois Pistoles, and the Lake St. John region as far east as Ha Ha Bay. The two chief objects were the listing of evidence indicating the epicenter, or origin, and an examination into the truth of the reports of damage sustained. The first object has been attained in a tentative way, and the second fairly definitely for the area concerned.

Without going into details it may be said that at present it is thought that the epicenter is in the mountainous region near the eastern boundary of the Laurentides Park. However, that section of the country is practically inaccessible at this season, and data can be better gathered there later, if promised reports from lumbering companies, together with other information already accumulated or still to come should not serve to settle the question definitely.

The fact must be recognized that considerable serious damage was done at several points; on the other hand, many of the reports were exaggerated and some were pure inventions. The damage was not so much a function of the distance from the epicenter as of the nature of the ground and the character of the buildings. The major damages were at Quebec, Shawinigan Falls, Malbaie, St. Urbain and the district near Rivière Quelle. They were in no case widespread or general, and applied in most cases to massive stone structures, without steel reinforcement, such as churches. Minor damages, such as falling of chimneys and breaking of windows, were somewhat more common. As the character of the ground was more rocky or the distance from the epicenter was greater the minor damages were limited to those caused by falling pictures, statues, bottles, etc. Where the damage was relatively serious the ground was found in every case to be sand or clay, usually on the side of a hill.

As in the case of all earthquakes of any considerable intensity, the main shock has been followed by a series of minor ones which are still felt at intervals. Earthquakes have occurred before in this region, the last severe one about half a century ago. Now that the accumulated stresses have, in all probability, been relieved, there is no occasion to anticipate further serious disturbances during the present generation. As an insurance for posterity, however, it would be well to pay some attention to location and methods of construction of new buildings. Where these are massive, and of stone or concrete construction without reinforcement by steel girders, it is preferable to have the foundation on rock or other solid substratum. Wooden or steel reinforced buildings are safe.

THE UNVEILING OF A TABLET IN HONOR OF THOMAS ALVA EDISON[1]

ON the scene where he conceived many of his great inventions and carried on the experiments which resulted in the perfection of his greatest work, at Menlo Park, N. J., a bronze tablet, commemorating these achievements, was unveiled in honor of Thomas Alva Edison on May 16. The tablet was the gift to the State of New Jersey of the Edison Pioneers, men who worked side by side with the inventor in the old days, and it was unveiled by Mrs. Edison, the inventor's wife, while prominent speakers related the tremendous effect his inventions had had upon the progress of mankind.

The inventor himself did not take an active part in the proceedings, but happy as a schoolboy sat on the platform and strained his ear to catch what was being said about him. He heard the affair being broadcast by a process which he had a share in perfecting and posed for the moving pictures which was among his many inventions. The tablet, set in a huge granite boulder with a base of concrete containing bricks from the foundation of the first Edison home in Menlo Park, is on the Lincoln Highway close by the original Edison laboratories and workshops. Participating in the affair were about six hundred of Mr. Edison's friends and former associates, who sat in chairs placed directly on the highway, the traffic over which had been diverted for the occasion. The tablet bears this inscription:

[1] *The Times*, New York.

On this site—1876–1882—Thomas Alva Edison began his work of service for the world to illumine the path of progress and lighten labor for mankind. This tablet is placed by the Edison Pioneers to attest the gratitude of the industries he did so much to create.

As a state monument, the tablet was formally given into the custody of Governor George S. Silzer by John W. Lieb, vice-president of the New York Edison Company and first electrician of the original power generating station built by Edison in New York in 1882, who presided over the ceremonies. In accepting the tablet, Governor Silzer said in part:

This is historic ground, for it marks a step in the progress of the world.

Here, in enduring bronze, is recorded for all time the fact that on this spot Thomas Alva Edison, by his genius, his industry and his ability, made some of the greatest discoveries the world has ever known, and thus made this a better world and a happier place in which to live.

It is especially gratifying that this should take place in the lifetime of him whom we honor to-day, and that the inspiration should have come from those who here labored with him and who shared with him the thrill of discovery and achievement.

In an address following the dedication of the tablet Dr. John Grier Hibben, president of Princeton University, recalled a visit he had made to the first Edison laboratory when he was a student at Princeton.

In my memory there is a permanent deposit of awe and reverence, as I think of the new light that came into the world. . . . This new discovery of light led inevitably to the revolution of power as well, and a new source of energy became available for man.

This illustrates one of the general tendencies of nature, that light is in some mysterious manner invariably connected with power. And this is true not only of nature, and particularly of the interaction of the forces of electricity and magnetism, but it applies as well to the activities of the mind and the moral and spiritual strivings and ambitions of man. Wherever we find light there is also the potential of power.

Pointing to the scene of the first Edison laboratory, a few feet from the tablet, Mr. Lieb in his dedication address declared:

It was here that the master dreamed great dreams and saw great visions, and with courage undaunted and constant faith, with perseverance and determination, he pursued not "the tenor of his way," but the uphill road of the climb of an Alpine peak, overcoming obstacles and disappointments at every hand in order to bring his bold conceptions to a practical fruition.

On this spot many inventions were made, many attempts launched to wrest from nature her secrets and many ingenious combinations were devised to bring the new agent—electricity—into subjection and make it the docile servant of man. From the beginning Edison saw that this new force would introduce a revolutionary economic factor into our lives. More than forty years ago he realized that the mere pressing of a button would place every man, woman and child in a new relation to their environment, vastly increasing the productive capacity, diminishing the drudgery and manual labor required in the home, lightening the way and lifting the load of mankind everywhere. The supreme confidence and indomitable spirit with which the goal was relentlessly pursued must remain for all time a cause for wonder and admiration.

Charles L. Clarke, president of the Edison Pioneers, spoke of the men who had worked so long with Edison and shared in his triumphs. Edwin W. Rice, Jr., chairman of the General Electric Company, declared that the discovery of the so-called "Edison effect" by Edison in his work on the incandescent lamp in 1883 together with other early Edison inventions paved the way for the modern radio art. Mr. Rice confessed that in the early years at Menlo Park he was "among the skeptics" but came to appreciate the inventor's genius. After reviewing the benefits which had come to mankind through a few of Edison's more important inventions outside of the electrical field, such as the telegraph instruments, the stock ticker, the typewriter, the electric pen, the mimeograph, the phonograph, the alkaline storage battery, the motion picture camera, and his contributions to the telephone and to the process of manufacturing portland cement, Mr. Rice said of his work in the electrical field:

Viewed from the standpoint of to-day, Edison's achievements of that early period appear almost miraculous. They have stood the test of forty years of the most extensive and intensive technical and commercial development of the electrical industry.

Samuel Insull, president of the Commonwealth Edison Company of Chicago, closed the addresses. He was intimately associated with Mr. Edison for many years, first as his private secretary and confidential adviser and later directing his manufacturing enterprises.

THE NAPLES ZOOLOGICAL STATION AND THE AMERICAN ASSOCIATION

THE American Association for the Advancement of Science has continued for another year its support of the American Association table at the Naples Zoological Station. The sum of five hundred dollars was appropriated for the station for the year 1925 and a like sum has now been appropriated for 1926. Members of the association who desire to occupy the table should make application to the permanent secretary's office as soon as they make their decision and can

state the approximate period for which the use of the table is desired. Information regarding the station, which has recently been successfully reorganized, may be secured from the director, Dr. Reinhard Dohrn, Zoological Station, Naples, Italy. Appointments for the American Association table since the reorganization are as follows:

December 10, 1924, to February 1, 1925: Dr. E. J. Lund, University of Minnesota.

February 1, 1925, to April 15, 1925: Dr. Otto Glaser, Amherst College.

April 15, 1925, to June 30, 1925: Dr. A. R. Moore, Rutgers College.

June 30, 1925, to October 15, 1925: No appointments.

October 15, 1925, to February 1, 1926: Dr. E. Newton Harvey, Princeton University.

It is to be noted that the summer period of 1925 is still vacant and that no appointments have yet been made for periods later than February 1, 1926.

BURTON E. LIVINGSTON,
Permanent Secretary

SCIENTIFIC NOTES AND NEWS

DR. JOHN MASON CLARKE, New York State geologist and paleontologist, director of the New York State Museum and of the science division of the Department of Education, emeritus professor of geology at the Rensselaer Polytechnic Institute, died at Albany on May 30, at the age of sixty-eight years.

DR. WENDELL CHRISTOPHER PHILLIPS, consulting aural surgeon to the New York Post-Graduate and Flushing Hospitals and aural surgeon to the Manhattan Eye and Ear Hospital, New York City, was elected at the Atlantic City meeting president of the American Medical Association for 1926 to 1927. Dallas, Texas, was chosen as the place to hold the next annual meeting. Dr. Philip Marvel, of Atlantic City, was elected vice-president.

THE Willard Gibbs gold medal has been awarded by the Chicago section of the American Chemical Society to Dr. Moses Gomberg, professor of organic chemistry in the University of Michigan.

DR. JAMES PERRIN SMITH, professor of paleontology in Stanford University, should have been included in the list of members of the National Academy of Sciences elected on April 29.

AMBROSE SWASEY, founder of the Engineering Foundation, was the guest of honor at a dinner given on May 14 at the Union League Club, New York, by the present and former members of the foundation, the trustees of the United Engineering Society and the officers and directors of the American Institute of Electrical Engineers, the American Society of Mechanical Engineers, the American Society of Civil Engineers and the American Institute of Mining and Metallurgical Engineers. Dr. Frank B. Jewett, a former vice-chairman of the foundation, made an address on "Permalloy cables for submarine telegraph."

THE Royal Horticultural Society, London, has awarded the Lindley gold medal to Albert C. Burrage, of Boston, president of the Massachusetts Horticultural Society and of the American Orchid Society, for his display of New England plants at the recent Chelsea show.

THE Royal Society of Edinburgh has awarded the Gunning Victoria Jubilee Prize for the period 1920-1924 to Sir Joseph Thomson, in recognition of his great discoveries in physical science; and the Makdougall-Brisbane Prize for the same period to Professor H. Stanley Allen, for his papers on the quantum and atomic theory.

WE learn from *Nature* that Wing Commander Harold E. Whittingham has been awarded the Chadwick gold medal and £100 prize for his work on sand-fly fever. The award is made under the provisions of the Chadwick Trust to such officer of the navy, army or air force medical service as shall during the preceding five years have "specially assisted in promoting the health of the men" of the service to which he belongs.

SIR WILLIAM HENRY ELLIS, managing director of John Brown and Company, Sheffield, a member of the council of the University of Sheffield and of the National Physical Laboratory, has been elected president of the British Institution of Civil Engineers.

LORD RONALDSHAY, president of the Royal Geographical Society, is about to resign that office, which he has held for the customary three years. At the anniversary general meeting of the society to be held on June 15, the council will propose that Dr. David G. Hogarth shall be elected his successor, Lord Ronaldshay becoming a trustee of the society in place of the late Lord Curzon of Kedleston.

THE Lawes Agricultural Trust Committee has appointed as its chairman Lord Clinton, in succession to Lord Bledisloe, who resigned on accepting the post of parliamentary secretary to the Ministry of Agriculture and Deputy Minister of Fisheries.

SIDNEY D. WELLS, who has been with the Forest Products Laboratory of Madison, Wisconsin, since 1911, has resigned to take charge of the Paper Mill Laboratories, Inc., of Quincy, Illinois. The new laboratories are being organized by a group of strawboard manufacturers with mills in Indiana, Illinois, Iowa and Kansas.

E. A. SWENSON has resigned his position as in-

structor in biology in Western Reserve University, in order to spend the next year in research work at the Wistar Institute of Anatomy.

P. J. WESTER, for fourteen years connected with the Bureau of Agriculture, Manila, P. I., first as horticulturist and later as agricultural adviser, who left Manila in January for the United States on accrued leave, has applied for retirement from the government service under the Osmena act. He will make his home in Washington, D. C.

ROSS G. PURDY has resigned as secretary of the American Ceramic Society, the resignation to take effect on March 1, 1926.

DR. WARO NAKAHARA, of the Rockefeller Institute for Medical Research, has been appointed associate pathologist at the Government Institute for Infectious Diseases, Tokyo Imperial University, and research associate in the division of experimental therapy at the Institute of Physical and Chemical Research, Tokyo.

DR. M. ALLEN STARR, professor emeritus of neurology at Columbia University, has been appointed official delegate by the state department to represent the medical profession at the centenary of the birth of Charcot.

DR. CHARLES L. PARSONS left for Europe on May 30 to attend the meeting of the International Union of Pure and Applied Chemistry at Bucharest. He will return about July 20, in time to be present at the Los Angeles meeting of the American Chemical Society.

PROFESSOR FRANK PELL UNDERHILL, chairman of the department of pharmacology and toxicology of Yale University, has accepted the invitation of the General Education Board to spend a year in travel as an observer of certain aspects of medical education in the leading universities of Europe.

DR. GEORGE H. SIMMONS, editor and general manager emeritus of the American Medical Association, has returned to Chicago after a tour of almost ten months through India, China and Japan.

DR. C. E. HELLMAYR, associate curator of birds in the Field Museum of Natural History, Chicago, sailed recently for Europe for the purpose of examining types of American birds preserved in various European museums.

THE National Geographic Society announces that Lieutenant Benjamin H. Riggs, of the Coast Guard Service, had been assigned to represent the U. S. Coast and Geodetic Survey as hydrographic officer to accompany the Donald B. MacMillan Arctic expedition.

PROFESSOR HEINRICH RIES, of Cornell University, will speak before the Institute of British Foundrymen in London in June on "The present status of our knowledge of sand testing."

DR. W. T. BOVIE, professor of biochemistry at Harvard University, gave a lecture to the Franklin Club of Akron and its guests at the University Club in Akron on the evening of May 18 on "The effect of light on growth and development."

DR. M. F. GUYER, of the University of Wisconsin, was the lecturer of the annual spring meeting of the honor agriculture society, Gamma Sigma Delta, at the Kansas State Agricultural College, on May 5. His subject was "Some biological aspects of democracy." On May 6, Dr. Guyer addressed the combined biological seminars, giving his data on the experimental modification of the germ plasm of rabbits, and that night he addressed the Science Club on some philosophical aspects of the experimental modification of the germ plasm.

PROFESSOR NIELS BOHR, of the University of Copenhagen, lectured on "Problems of the quantum theory," at the Cavendish Laboratory, Cambridge, on May 15.

DR. B. BROUWER, professor in the University of Amsterdam, gave a lecture entitled "The projection of the retina in the brain," on May 19, at the University of Sheffield.

THE centenary of the birth of Charcot was celebrated in Paris at the end of May. If plans were carried out Professor Pierre Marie delivered a eulogy of Charcot at the Academy of Medicine on the afternoon of May 26, and on the evening of the same day at a meeting at the Sorbonne, which was attended by the President of the Republic, M. Babinski delivered an address, and was followed by the official delegates of foreign governments. Addresses were given by the dean of the Paris Faculty of Medicine, by representatives of the Paris Academy of Sciences, the Academy of Medicine, the Pasteur Institute and a number of medical societies. On May 27 a visit was paid to the Clinique Charcot and the Salpêtrière. On the afternoon of the following day the Municipal Council of Paris and the General Council of the Seine held a reception at the Hôtel de Ville. There will be a social evening of the Royal Society of Medicine on June 15, with an exhibition in the library of books and articles by Charcot and his pupils.

DR. ALFRED TUCKERMAN, known for his work in chemistry and bibliography, especially for his index to the literature of the spectroscope and of thermodynamics, died at Newport, R. I., on May 25, aged seventy-seven years.

UNIVERSITY AND EDUCATIONAL NOTES

GROUND has been broken for the construction of five of the six buildings for Northwestern University, to be erected at a cost of $5,350,000, on McKinlock Memorial Campus at Lake Shore Drive and Chicago Avenue. Those who made possible the construction of the buildings are: Mrs. Montgomery Ward, who gave $3,000,000 for the medical-dental center; Mrs. Levy Mayer, $500,000 for the law school building; William A. Wieboldt, representing the Wieboldt Foundation, $500,000 to complete the school of commerce; George A. McKinlock, $500,000, which made possible the purchase of the campus; Mrs. George R. Thorne, $250,000 to erect an auditorium, and Elbert H. Gary, $100,000 for the Gary Law Library.

A BEQUEST of $50,000 to Harvard, the income to be used by the Harvard Medical School for research in etiology and therapeutics of diseases of men, is provided in the will of William H. Wellington, of Boston.

PROMOTIONS at Yale University include Dr. Alan Mara Bateman, editor of the *Journal of Economic Geology,* to a professorship of economic geology; Dr. Arthur Joseph Hill, to a professorship in organic chemistry; Dr. Alois Francis Kovárik, to a professorship in physics, and Dr. Egbert Joseph Miles, to an associate professorship in mathematics.

PROFESSOR CHARLES SHATTUCK PALMER will rejoin the staff of the department of chemistry of Northwestern University in September. For the past year he has been research chemist of the department of scientific research of the Institute of American Meat Packers.

DR. SAMUEL E. POND, of Washington University, has been appointed assistant professor of physiology at the University of Pennsylvania.

DR. ENGLISH BAGBY, assistant professor of psychology at Yale University, has been appointed associate professor of psychology at the University of North Carolina. Besides his teaching work he will be in charge of research problems in student personnel.

PROFESSOR B. HELFERICH, of Frankfort-on-Main, has been called to Greifswald to fill the chair of chemistry made vacant by the removal of Professor R. Pummerer to Erlangen.

DISCUSSION AND CORRESPONDENCE

FRESH-WATER MEDUSAE IN THE PANAMA CANAL ZONE

AT various times during the past eighteen years SCIENCE has contained announcements pertaining to the presence of fresh-water medusae in different parts of the United States. In Washington, D. C., Kentucky, Indiana and Georgia the specimens have been found which formed the basis for these announcements, and *Craspedacusta sowerbii* Lankester is the species involved.

It gives me pleasure to announce the discovery of specimens of this species in Gatun Lake, in the vicinity of the Barro Colorado Island Laboratory in the Panama Canal Zone. Mr. James Zetek, the resident custodian of the laboratory, made a collection December 1, 1924, and forwarded the specimens to the writer for identification. They had been preserved in alcohol. In response to a request for more material additional specimens were sent by Mr. Zetek. They were collected on January 24, 1925, and preserved in formalin. The later collection included specimens of various sizes ranging from 9 mm to 19 mm in diameter and were in excellent condition. Only males have been found among the specimens examined.

A comparison between the new specimens and others which the writer had previously received from Professor Garman, of Kentucky, and Professor Payne, of Indiana, leaves no doubt in the mind of the writer that they all belong to the same species; and furthermore that the specimens from China, described by Oka as *C. kawaii,* were probably of the same species. Oka describes the arrangement of tentacles in seven sets and as differing from that in *C. sowerbii,* in which the tentacles had been described as forming three sets. An examination of the Gatun Lake specimens reveals an arrangement which corresponds closely to that described by Oka. A similar arrangement is found in the specimens received from Kentucky and Indiana. "Die Tentakel I, Ordnung" of Oka corresponds to the set 1 of Lankester and others, the perradial tentacles. The second set "secondary tentacles" of Lankester and some others is equivalent to Oka's "Die Tentakel II–IV, Ordnung" and is about 28 in number. The "intermediate set" of Payne includes also Oka's "V, Ordnung," making about 60 in that set. The third set of most writers would include Oka's "V–VII, Ordnung" or his "VI-VII." It is the opinion of the writer that Oka would very likely have written a similar description of tentacle arrangement had he been studying Gatun Lake specimens. The number of tentacles in the larger specimens recently received is approximately 400, and that of the lithocysts is not far from 200.

Mr. Zetek has suggested that the writer make a preliminary announcement of the discovery, and has expressed an intention to prepare a general report

on the various features connected with this new occurrence of the widely distributed *C. sowerbii.*

The Barro Colorado Island Laboratory recently established by the Institute for Research in Tropical America gives promise of being a source for a great variety of highly interesting material and a very attractive center of research activity. An account of the laboratory and its remarkable surroundings appeared in the *Journal of Heredity,* March, 1924, Vol. XV, No. 3.

FRANK SMITH

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THE TAXONOMY AND RANGE OF POISON IVY

THERE are several statements in the botanical part of my book "Rhus Dermatitis"[1] that should be revised in accordance with recent investigations:[2]

On page 3 it is stated on the authority of Nuttall[3] that the leaves of the male and female plants of the western poison oak (*Rhus diversiloba* T. & G.) differ in shape. This has not been found to hold true.

On page 4 the following statement occurs, "The only botanical ground for the separation of the two (*Rhus Toxicodendron* L. and *Rhus diversiloba* T. & G.) into different species is a slight difference in the shape of their leaflets." It is now known that these species are altogether distinct, as they possess excellent fruit and flower characters.

In regard to the geographical distribution of western poison oak, the herbarium specimens listed on pages 11 to 13 were not all seen by the writer and from present information[2] its habitat seems to be limited to California, Oregon and Washington.

The writer's studies on the taxonomy of the poison ivy group[2] in North America lead him to conclude that there are four species in this area, namely: *Rhus quercifolia* (Michx.) Steud. (eastern poison oak) from New Jersey southward and westward to Texas; *R. diversiloba* T. & G. (western poison oak) in California, Oregon and Washington; *R. Toxicodendron* L. (poison ivy) of general distribution exclusive of California, and *R. greenei* McNair confined to Lower California. *R. diversiloba* has a *forma radicans* and *R. Toxicodendron* has a *forma radicans,* a *forma malacotrichocarpum* and a variety *eximia.*

JAMES B. MCNAIR

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1 "Rhus Dermatitis, Its Pathology and Chemotherapy," University of Chicago Press, Chicago, Ill.

2 "The Taxonomy of Poison Ivy," Field Museum Publications, Botanical series, Vol. 4, No. 3, March 14, 1925, Field Museum of Natural History, Chicago, Ill.

3 Nuttall, in Torrey and Gray, "Flora of North America," Vol. I, p. 218, 1838.

A NAME FOR THE N IN COS NT

VARIOUS authors have recognized the desirability of having a name for the quantity n which represents 2π-times-the-frequency of a simple harmonic motion and which appears in the equation

$$x = A \cos (nt - \varepsilon).$$

Professor Lamb states[1] that Lord Kelvin and Professor G. H. Darwin have used the term *speed;* Professor Lamb himself has suggested[2] the name *rapidity;* Mr. Jeans[3] calls it *frequency;* Mr. Albert Campbell[4] has called attention to the French term *pulsation,* and has suggested as an English equivalent the word *pulsatance;* I have suggested[5] translating the German term *Kreisfrequenz,* and calling the n a *circular frequency.* Other names may also have been suggested, but none of them has been generally adopted.

Of the various suggested names, the words *speed* and *frequency* are now very often used with other meanings. Any of the terms *rapidity, pulsatance, circular frequency* might be adopted, but I am now suggesting still another. The reason for desiring a name for this quantity is the circumlocution that is often necessary when we have no such name. The objection to a new term is the increase in the number of names that we must remember. If a term naturally suggests the quantity which it names, it is a better term —other things being equal—than one which does not so readily suggest the quantity.

I am proposing that we call n the *π-frequency* of the motion. This term is easily spoken and easily printed; it at once suggests a close relationship between frequency and π-frequency, and if a student has difficulty, when he first meets these quantities, in remembering whether the π-frequency equals the frequency multiplied by 2π or divided by 2π the term π-frequency suggests multiplication.

I should be glad, and I presume many others would, if those of us who often have occasion to refer to this quantity would adopt some name for it, and it seems to me that a good name would be *π-frequency.*

Since writing the above I have found that Voigt[6] has used still another term. He calls n the *vibration index* of the motion. This does not seem to be as good a name as *π-frequency.*

ARTHUR TABER JONES

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1 "Hydrodynamics," ed. 3, p. 237.

2 "Dynamical Theory of Sound," p. 10.

3 "Theoretical Mechanics," p. 263.

4 Phys. Soc. Lond., Proc., 31, p. 81, 1919.

5 SCIENCE, 48, p. 447, 1918.

6 Wied. Ann., 40, p. 654, 1890.

TITANIC ACID IN THE POTATO TUBER

IN Bulletin 267 of the Colorado Experiment Station, entitled "Titanium, barium, strontium and lithium in certain plants," the writer considered the findings relative to titanium doubtful to a great degree, because of the contamination of ashes of the plants by dust that had been blown on to the plants.

This contamination amounted, in the case of a tobacco, to over 50 per cent. of the ash, also in corn leaves. As this contaminating material contained titanic acid, it became doubtful whether the plants contained any or not. All samples of ash prepared from field-grown plants contain more or less dust and sand.

The most satisfactory material found in the progress of that work was the ash of the potato tuber which can be well washed and a fairly clean ash obtained. Recently I had sufficient ash of this sort to justify an attempt to determine the titanic acid quantitatively. It was not only present, as in the former case, but amounted to 0.08 per cent. of the ash.

It seems probable that it was really present in the ashes proper of the other plants, most liberally in the ash of the corn leaves.

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CHEMICAL SPELLING CONTINUED

FOR a year or two very little mention has been made of chemical spelling in SCIENCE, but since considerable interest was manifested in the subject at the start, there is doubtless some curiosity felt as to its present status.

Chemical spelling is now in its fourth year at the West Virginia University. Four annual contests have been held here, including one during the first week in May of this year. The five students who received the highest rank in each of the preceding contests were granted "Roll of Honor" certificates bearing their names and the university seal. A copy of the certificates from each of these contests has been framed for the department of chemistry.

Over three hundred students entered the spelling matches each year and the winners are justly proud of their achievement. These certificates, hanging in a conspicuous place in the chemistry building, serve to remind first-year students of the impending contest, spurring them on to greater efforts to excel, not only in chemical spelling, but in all their chemical work.

Several other institutions are now beyond the experimental stage in chemical spelling, and in at least one section of the country, namely, the southwestern, intercollegiate spelling matches have been held. The progress of chemical spelling has been retarded to some extent by the fact that no suitable list of words and formulas was available in print and therefore had to be prepared. Mimeographed lists of about twelve hundred words were supplied to the students at the West Virginia University and a few other institutions, but these lists proved to be inadequate.

In order to meet the needs of the contests this spring I have prepared three lists of words, together with their respective chemical formulas, which have now been published in a book called "A *Pronouncing* Chemical Formula Speller," which appeared about April 20.

There are about three thousand inorganic and one thousand organic compounds included, besides about three hundred of the more common minerals. The words in these three lists are hyphenated, accented and supplied with diacritical marks. A key to pronunciation, as well as directions for holding contests, have also been included. The organic list has been carefully looked over and revised by Professor E. Emmet Reid, of Johns Hopkins University. As a matter of interest to those who are planning chemical spelling contests, it should be said that about fifteen hundred questions and answers, involving the typical reactions of the elements, have been included, the answers being expressed in the form of balanced equations.

A book of this sort is almost indispensable to chemical spelling and should facilitate the holding of intercollegiate contests. It would also be of value to students and instructors as a reference book. The 1925 International Atomic Weights and Atomic Numbers of the elements have been included.

C. A. JACOBSON

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MUSSELSHELL RIVER

APROPOS of the "Muscle Shoals" *vs.* "Mussel Shoals" question it may be of interest to note that what is now known as "Musselshell River," a tributary of Missouri River in central Montana, was formerly known as "Muscleshell River."

The form "Muscleshell" is used in H. V. Hayden's report on the Geological Exploration of the Yellowstone and Missouri Rivers, which he made as assistant to Brigadier General W. F. Raynolds in 1859–60. General Raynold's report uses the same form, and both seem to have followed the example of Lieutenant J. Mullan who went through the country in 1852.

In the report on the expedition of 1875 from Carroll, Montana, to Yellowstone National Park and return, under Captain William Ludlow, the form "Mus-

selshell" is used. Messrs. G. B. Grinnell, E. S. Dana and R. P. Whitfield were the scientists of this expedition.

HAROLD S. PALMER

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SCIENTIFIC BOOKS

La "Thiende" de Simon Stevin. Facsimilé de l'édition originale plantinienne de 1585. Avec une introduction. Par H. BOSMANS, S. J. Édition de la Société des Bibliophiles Anversois, No. 38. Anvers, Marché du Vendredi, 22. 1924. Pp. 42 + 37. 15 Belgian Francs.

THIS facsimile reproduction of the earliest presentation of the theory of decimal fractions will be welcomed by every one interested in the history of mathematics. Copies of the original editions of some of the works of Stevin are very rare. In fact, as Bosmans points out, since the destruction of the Library of Louvain no copies of the Appendice Algébraique de Simon Stevin, 1594, seem to exist. That appendice contained a resolution of numerical equations by approximation, published six years earlier than Vieta's process of approximation, and is regarded by some as the superior of the two. Original copies of Stevin's booklet on decimals, La Thiende, are also very rare. At the time of the destruction of the Library of Louvain, the copy belonging to that library had been loaned to Professor Bosmans in Brussels and was thus saved. Bosmans has been able to learn of only four copies of this now extant. Hence his facsimile edition is a praiseworthy step toward conservation.

Bosmans gives a long historical introduction which in itself is very valuable, for he has for many years made a study of sixteenth and seventeenth century mathematics and especially of the contributions made at that time by mathematicians of Belgium and Holland. In that field he speaks with authority.

The charm of Stevin's treatment of fractions lies in his quaint notation. Though clumsy in practice, it is of interest, because the fundamental idea of an exponential notation (powers of one tenth) are involved in it. Moreover, the same symbols, with a slightly different interpretation, appear in Stevin's algebra.

FLORIAN CAJORI

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Mosses with a Hand Lens. By A. J. GROUT. Third edition. Pp. XV + 339. Published by the author (1 Vine St., New Brighton, N. Y.), 1924.

As the founder and until recent years editor of the *Bryologist* (the only journal in the English language which is devoted to bryophytes), as one of the organizers and first president of the Sullivant Moss Society, and as the author of several books and numerous papers on the subject, Dr. Grout has contributed more than any one else in this country toward popularizing the study of the mosses. The first edition of "Mosses with a Hand Lens" was published in 1900 as a thin volume of about 75 pages and, save for brief mention of the sphagnums, dealt exclusively with the true mosses. The present edition, more than four times the size of the first, includes not only the sphagnums and the true mosses but the liverworts as well, the author's treatment of this latter group which appeared in the second edition having been revised and amplified by Dr. M. A. Howe. The book comprises descriptions and keys to the mosses and liverworts, based for the most part on characteristics which can readily be made out without the aid of a compound microscope. It is copiously illustrated with no less than 83 plates and approximately 200 text figures. Noteworthy among these are a large number of photographs, for the most part admirably executed. The book is the best non-technical treatise on the bryophytes of this country that has yet appeared, and as such will be welcomed by all who are interested in the study of this rather difficult group of plants.

G. E. NICHOLS

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SCIENTIFIC APPARATUS AND LABORATORY METHODS

WATERPROOFING LABELS FOR WET SPECIMENS

THE impaired value of specimens without the identifying tag is well known to laboratory workers and collectors. In the case of wet specimens especially the fading of the lettering and erosion or tearing of paper labels is serious, but has a remedy which some field and laboratory workers may not yet have found. The remedy is to waterproof the labels. Perhaps the best material is paraffin. It is apparently no more difficult to provide and use paraffin than to provide and use a so-called waterproof ink.

The label may be written with anything sufficiently opaque: lead pencil, red or blue pencil, any kind of ink. Typewritten labels are best. If the labels are written in a block on a rather large sheet, a few shavings of paraffin may be scattered upon it and melted over flame or oven. A pot of melted paraffin will at times have certain advantages. For an occasional label, a small bottle of paraffin in saturated solution may be kept on hand. Xylol is the best solvent tried. After dipping the label and dry-

ing for a few minutes, nearly perfect waterproofing is secured.

The lettering of labels prepared as described is clearer than before treatment, except in the case of lead pencils, and will not run. The paper is stiffer and the whole label will stand wear to a remarkable degree. In the case of labels waterproofed ten years ago, no deterioration can be observed either in alcohol or formaldehyde. The label will not act as a wick if inserted beside the cork.

Celluloid and collodion in quick drying solvents have promise of preserving wet labels, but thus far have not shown themselves as satisfactory or adaptable to usual conditions as paraffin.

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SPECIAL ARTICLES

ON THE CONTENTS OF OXYGEN IN THE OCEAN ON BOTH SIDES OF PANAMA

IN January, 1922, the Danish *Dana* Expedition had an opportunity of making comparison between the oceanographical (physical and biological) conditions on both sides of Panama.[1]

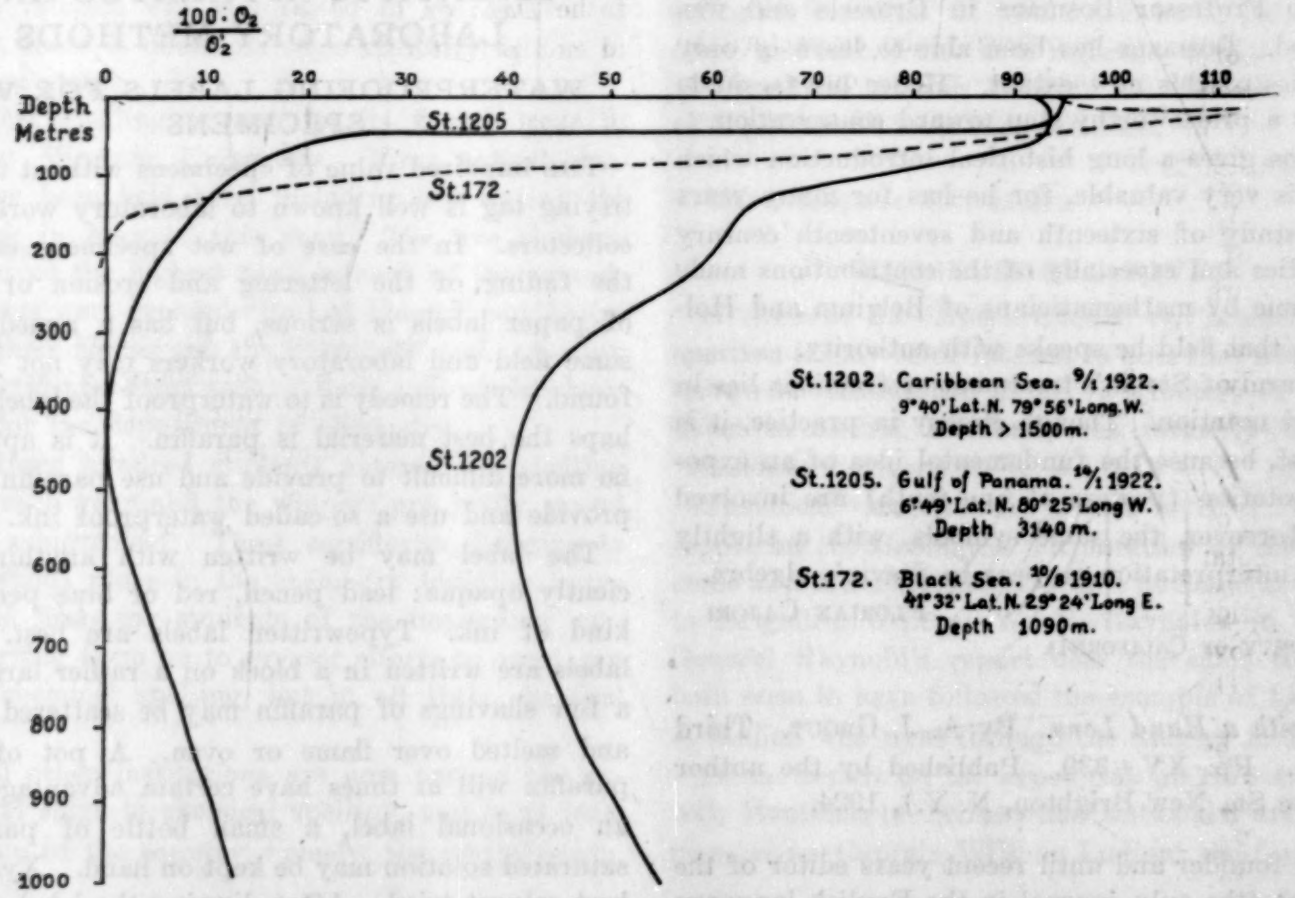
I mention here only a single feature—the vertical distribution of the quantity of oxygen in the sea.

The oxygen content was determined on board the *Dana* by Dr. N. C. Andersen, using the Winkler titration method.[2]

The figure shows the oxygen content at depths from 0 to 1,000 m at two of our stations, one (1,202) on the Caribbean, the other (1,205) on the Pacific side. By way of comparison, I have included a station (172) taken in 1910 from the Danish research steamer *Thor* in the Black Sea.

We see that at the surface the two stations do not differ much, the water in both cases being nearly saturated with oxygen. The similarity, however, goes no farther. The Atlantic (Caribbean) station shows no difference between the surface content and that at 50 m, whereas the oxygen content on the Pacific side has at a depth of 50 m dwindled to only 25 per cent., *i.e.*, even at this slight depth, the water contains only one fourth of the amount of oxygen it *could* contain if saturated therewith. And at a depth of about 150 m, the oxygen content has further diminished to only 10 per cent.

At a depth of 4–500 m we find, for both stations, the minimum value for oxygen content, the quantity



[1] For the hydrographical work of the *Dana* Expedition in the Atlantic and Caribbean, see J. N. Nielsen, "The hydrography of the *Dana* Expedition" (London, *Nature*, 1925).

[2] See "Report on the Danish Oceanographical Expeditions 1908–10 to the Mediterranean and Adjacent Seas," Vol. I, p. 191. Copenhagen, 1912.

thereafter increasing slowly and gradually towards the bottom.[3]

The absolute values show a great difference between the stations; the Atlantic minimum lies between 40 and 50 per cent., whereas the Pacific is close on 0; *i.e.*, at depths between 400 and 500 m, the water here *contains practically no oxygen at all.* We found the same thing at all the *Dana* stations in the Pacific off Panama.

The various deep sea expeditions, from the *Challenger* onwards, which have investigated the quantity of oxygen in the ocean, found similar conditions to those at our Station 1,202 in the Caribbean Sea, with minimum values varying somewhat with the latitude; higher at a distance from and lower near to the equator.

As far as I am aware, however, there is no previous instance on record of the finding of such low values in the open sea as those noted by the *Dana* off Panama in January, 1922.

In partly enclosed basins, such as the Black Sea, for instance, and certain parts of the Baltic, there may, it is true, be a lack of oxygen deep down, as in the case of our *Thor* station 172 in the Black Sea, 1910, where the quantity of oxygen diminished, from saturation at the surface, to only 2.4 per cent. at 150 m depth, and reached 0 at about 200 m. But as shown by the Black Sea curve in the figure here given, there is a shortage of oxygen here from barely 200 m right to the bottom, showing that we have an entirely different type to deal with here in the enclosed Black Sea. It is precisely the characteristic feature of the open sea that the oxygen content, after falling to an intermediate minimum, again increases towards the bottom, as both the Caribbean and the Pacific stations show.

The operations of the *Dana* in the Pacific did not extend far enough outside the Gulf of Panama to afford further information as to the cause of this remarkable shortage of oxygen. Generally speaking, it must be a case of "old" or stale water, *i.e.*, water which has not been in contact with the atmosphere for a long time; its origin, however, I am unable to determine. Another cause of the oxygen shortage is undoubtedly to be found in the wealth of animal life in the intermediate and deeper water layers at these Pacific Stations, as this would of course consume a great deal of oxygen. After working for a long time in the Atlantic, we were surprised at the great quantities of bathypelagic animal forms brought up by our nets on the Pacific side of Panama. And our astonishment was not lessened on learning how small was the amount of oxygen in the water of these deeper layers.

I give here the quantities of plankton in our horizontal hauls at stations 1,205 and 1,202 for those depths at which the same implements were used from both stations, so as to permit comparison of the yield. It should be noted that the depth at which the net actually fished answers roughly to half the length of wire paid out.

Meters of wire out.	Quantity of plankton (ccm).	
	St. 1,205.	St. 1,202.
50	100	350
100	900	250
300	1,000	250
600	1,000	100

At some of the other Pacific stations, the quantity of plankton in the neighborhood of the surface was considerably greater than at station 1,205.

It would, of course, be quite incorrect to conclude, from the above figures, that the paucity of oxygen at the Pacific station (1,205) is the cause of its richer bathypelagic fauna, as compared with the Caribbean station. But the *Dana* stations off Panama undoubtedly show that a wealth of bathypelagic animal life can exist in waters of a lower oxygen content than we had reason to suppose.

It would be very interesting to investigate, by means of large vertical closing nets, the quantity of plankton in that portion of the column of water where the oxygen minimum is situated; the brief stay of the *Dana* on the other side of Panama, however, did not permit of this.

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[3] To between 30 and 40 per cent. at about 3,000 m depth at St. 1,205.

THE PENNSYLVANIA ACADEMY OF SCIENCE

THE Pennsylvania Academy of Science held its second annual meeting at Harrisburg, Pennsylvania, April 10 and 11. The morning of April 10 was given over to meetings of committees. In the afternoon the president, Dr. O. E. Jennings, of the University of Pittsburgh, gave his address, after which and on the morning of April 11 the following papers were presented:

Sporobolus uniflorus Muhl. in Pennsylvania: E. M. GRESS.

Demonstration of the life history of the earthworm: S. HOFFMAN DERICKSON.

A double turtle of the genus Chrysemys: S. HOFFMAN DERICKSON and V. EARL LIGHT.

Observations on hydra in limestone springs during the winter months: RAY A. TROUTMAN.